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# Using NASA Satellite and Model Analysis for Renewable Energy and Energy Efficiency Applications

*Paul Stackhouse (NASA LaRC)*

*With grateful acknowledgement to SSAI Team Members,  
NASA Partners at GISS, GMAO, and LaRC ASDC  
and Partners at DOE NREL and PNNL,  
NRCan RETScreen, USGS, USDA, State University of New  
York-Albany, Univ. of Ga, Univ. of Neb.  
And numerous small companies*



# Talk Organization

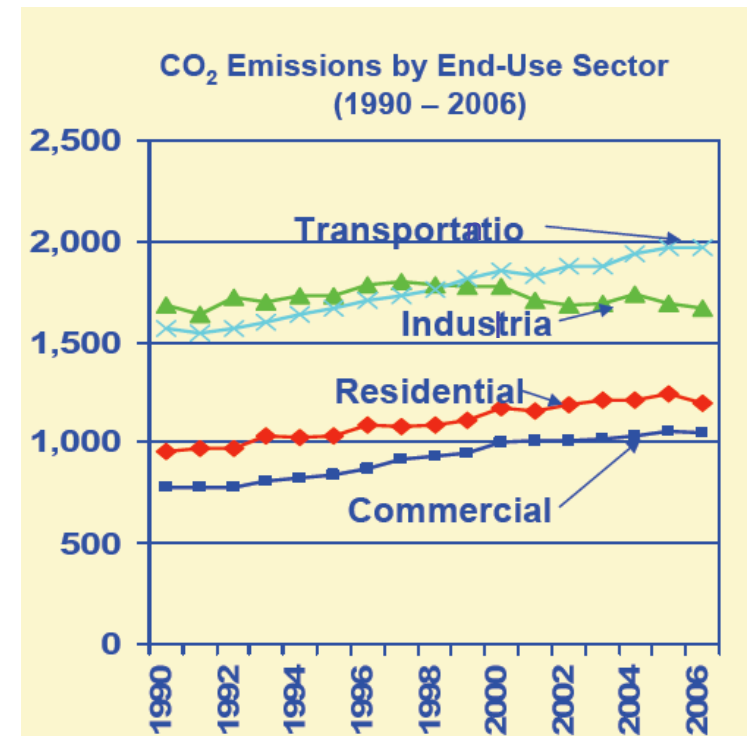
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- *NASA Science Objectives*
- *From Science to Climate and Energy Applications*
- *Developing Successful Applications in Energy - SSE History*
- *Current Energy Application Successes*
- *New Energy and Climate Projects*
- *Conclusions*



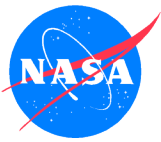
# Energy & Climate Change Challenge

- Energy demand is rapidly increasing.
- IPCC: 90% probability that climate change is due to anthropogenic GHG emissions.
- Worldwide, industry efforts are underway and policies are being enacted for mitigating and adapting to climate change through reduction of GHG.
- US and International scientific and applied research priorities are being planned to obtain these goals (CCSP/CCTP, NRC Decadal Survey, USGEO, GEO)
- Energy efficiency/renewable energies growing 30-50% per year; represent one solution to face issues.



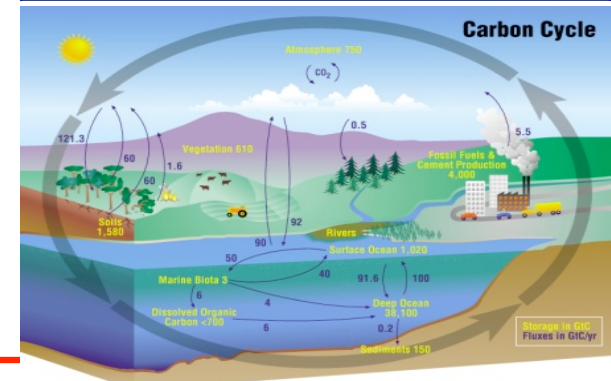
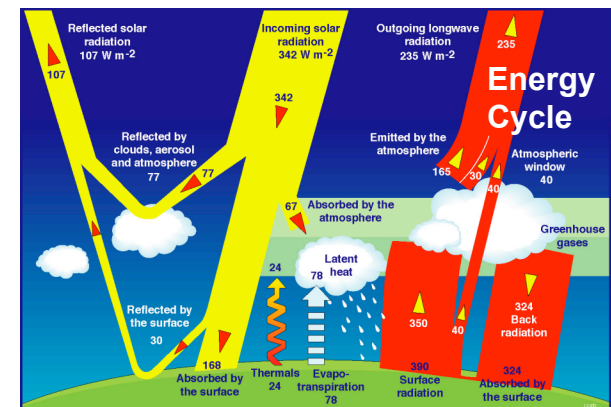
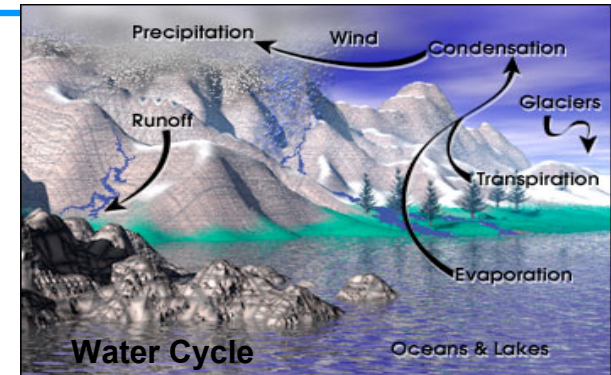
Source: Energy Information Administration

**Challenge: Apply NASA scientific expertise, models, and satellite-derived and in-situ measurements in developing applied science data sets for industry, academia, and policy makers in the arena of climate change.**



# Researching Science Questions

- *How is the global Earth system changing?*
- *What are the primary forcings of the Earth system?*
- *How does the Earth system respond to natural and human-induced changes?*
- *What are the consequences of changes in the Earth system for human civilization?*
- *How well can we predict future changes to the Earth system?*

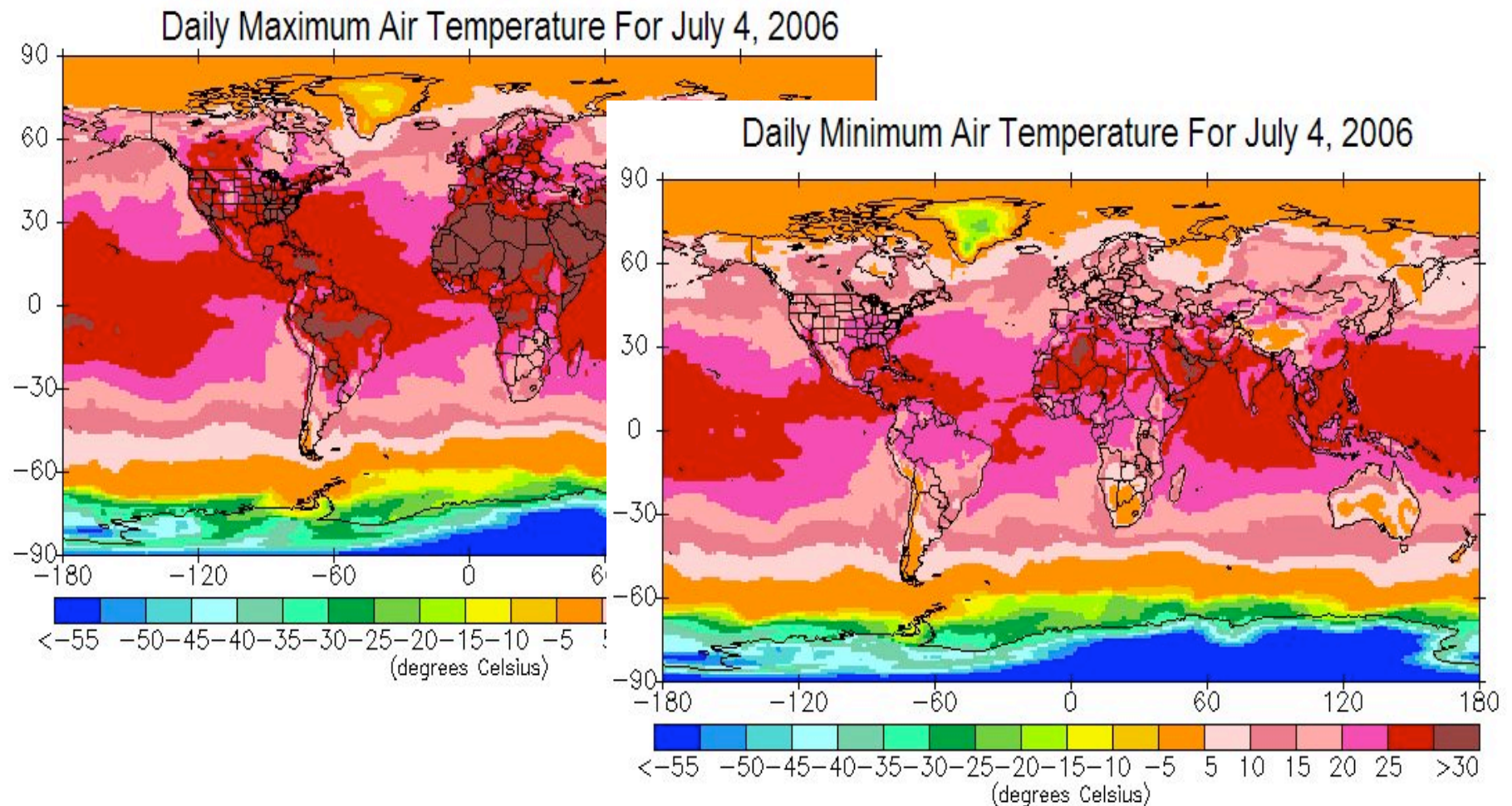






# Relevant NASA Science Data Sets

## *Meteorological Information from GMAO*

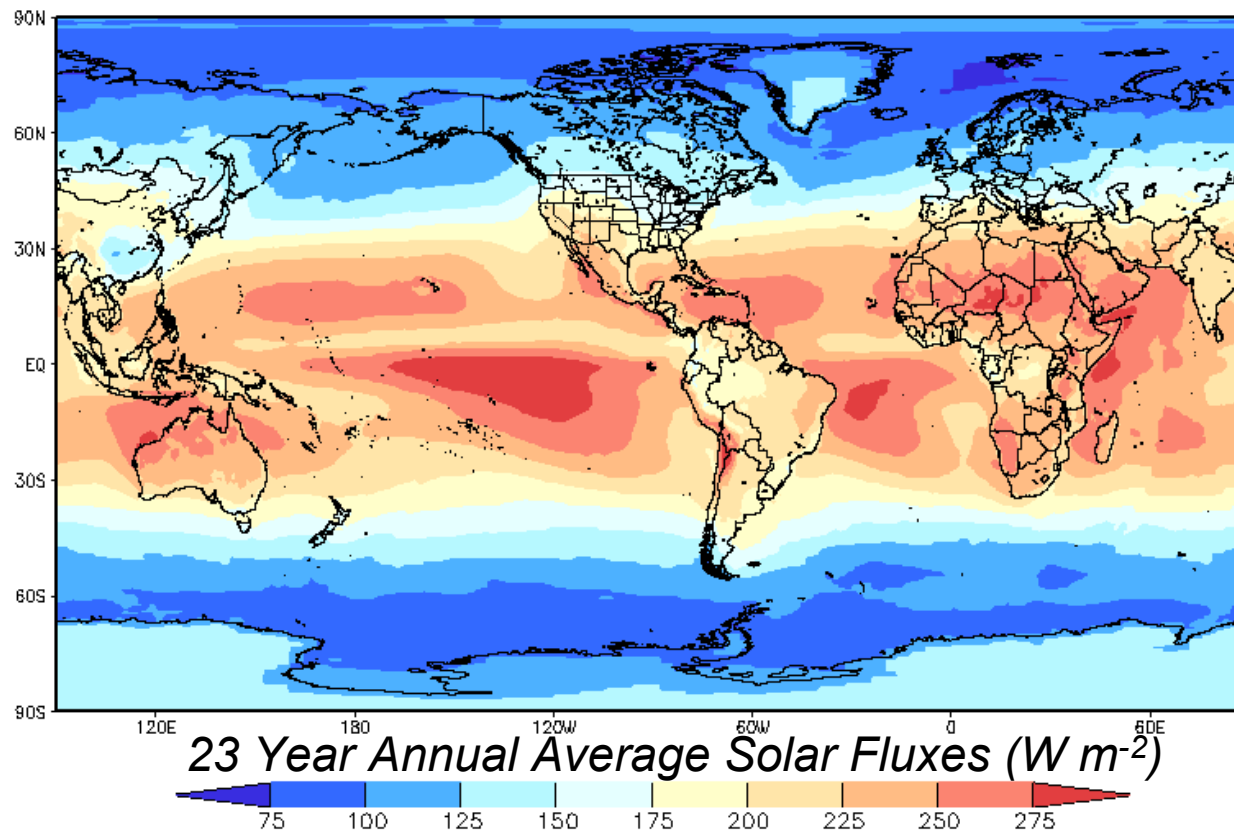




# Relevant NASA Science Data Sets

*GEWEX Surface Radiation Budget: 23 years of cloud (from ISCCP), SW and LW fluxes at TOA and Surface*

**GEWEX SRB SW v3.0 (ISCCP, GMAO)**

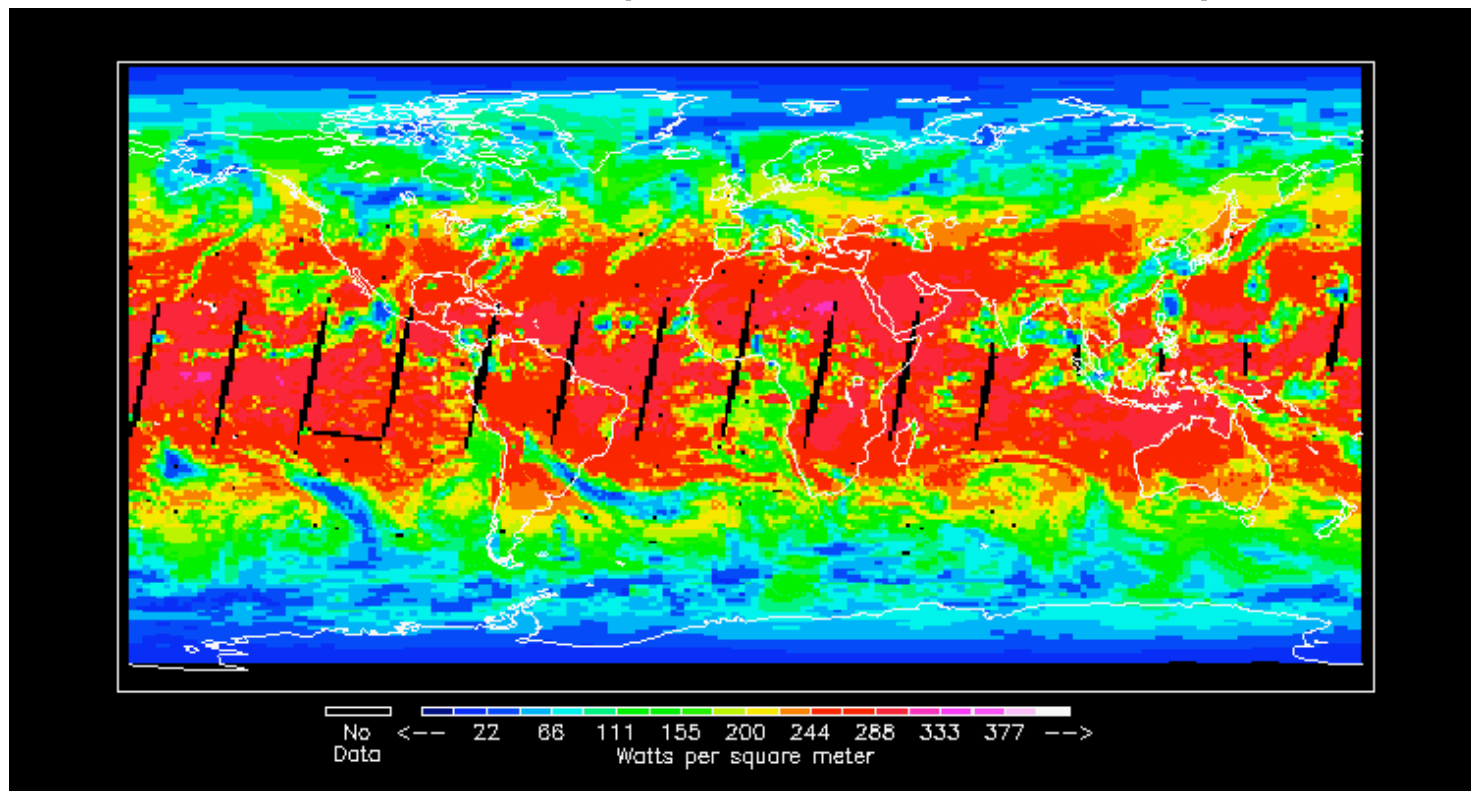




# Relevant NASA Science Data Sets

*FLASHFlux: Global TOA and Surface Fluxes within  
1 week of observation from Terra and Aqua*

***FLASHFlux (CERES/MODIS, GMAO)***



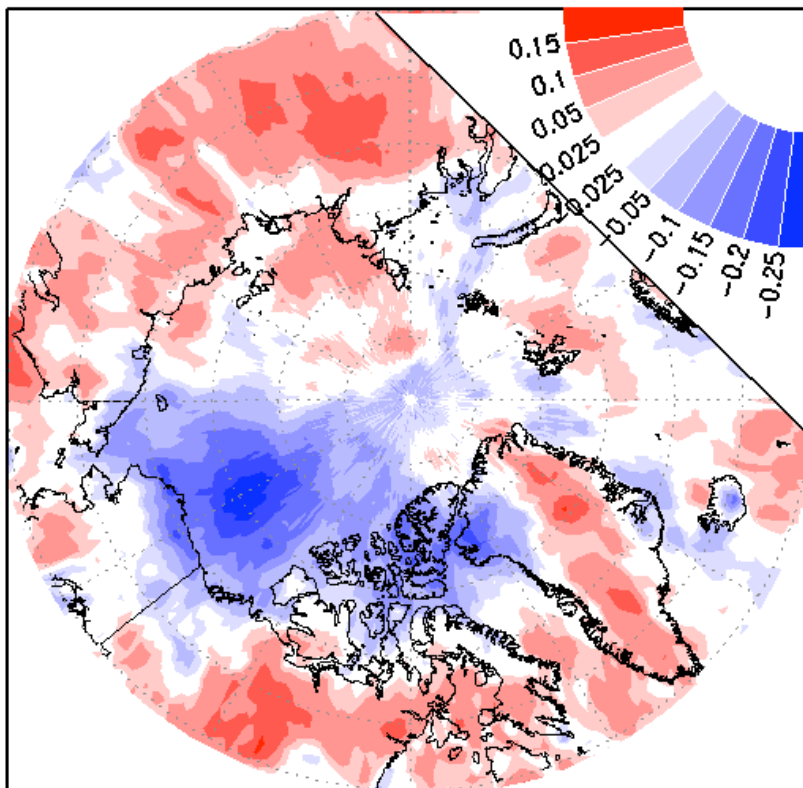
***Daily Average Solar Irradiance ( Wm<sup>-2</sup>)***



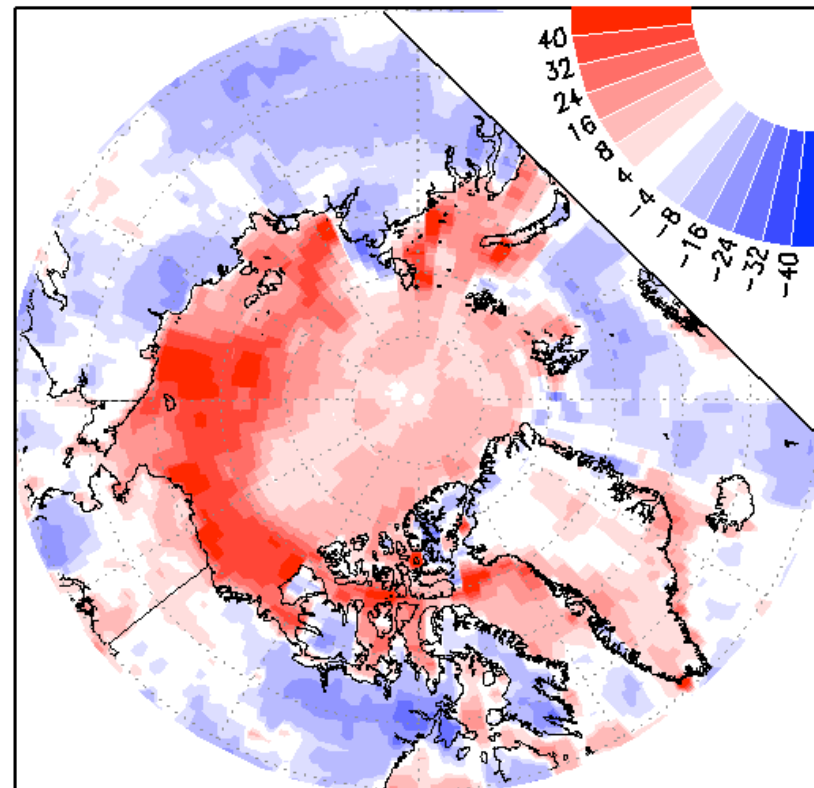
# Relevant NASA Science Data Sets

## *FLASHFlux: Near-Real Time Energy*

Summer 2007 minus Summer 2000-2004 Mean for Arctic



Cloud Fraction



Surface Total Net Energy





# The POWER Project

## POWER = Prediction of Worldwide Energy Resource

Objective: Improve the Nation's public and private capability for integrating environmental data from NASA's satellite-based analysis and modeling research into sound management of energy production and energy efficiency systems.

### Goals:

1. Establish partnerships to facilitate the integration and adaptation of NASA satellite analysis and modeling data into electric power industry Decision Support System's (DSS) and databases.
2. Target such datasets for Electric Power, Renewable Energy, Energy-Efficient Building Design and Biomass Crop Development Industries
3. Transition operational capabilities to government and/or private sector entities.



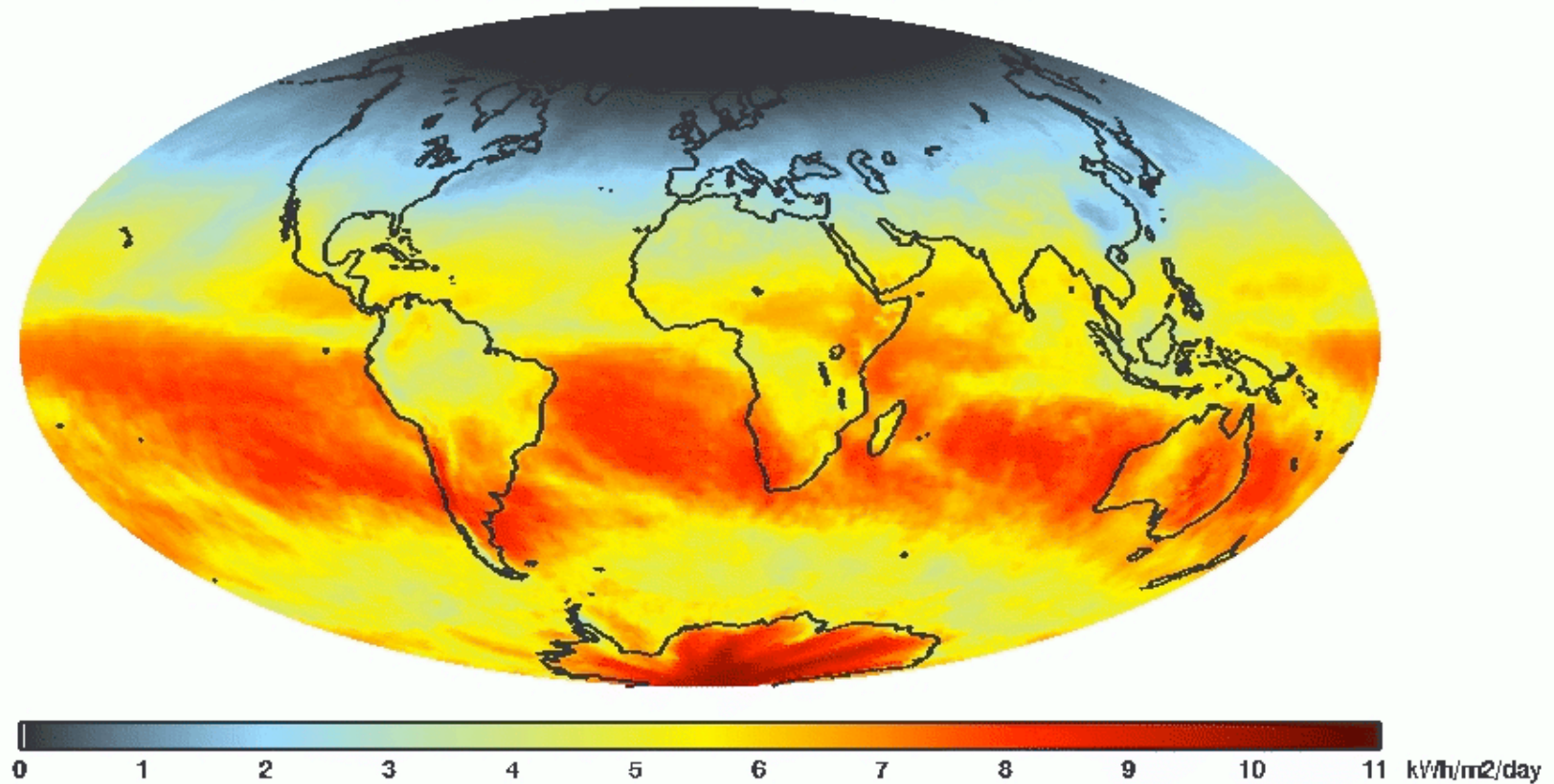


# Relevant NASA Science Data Sets

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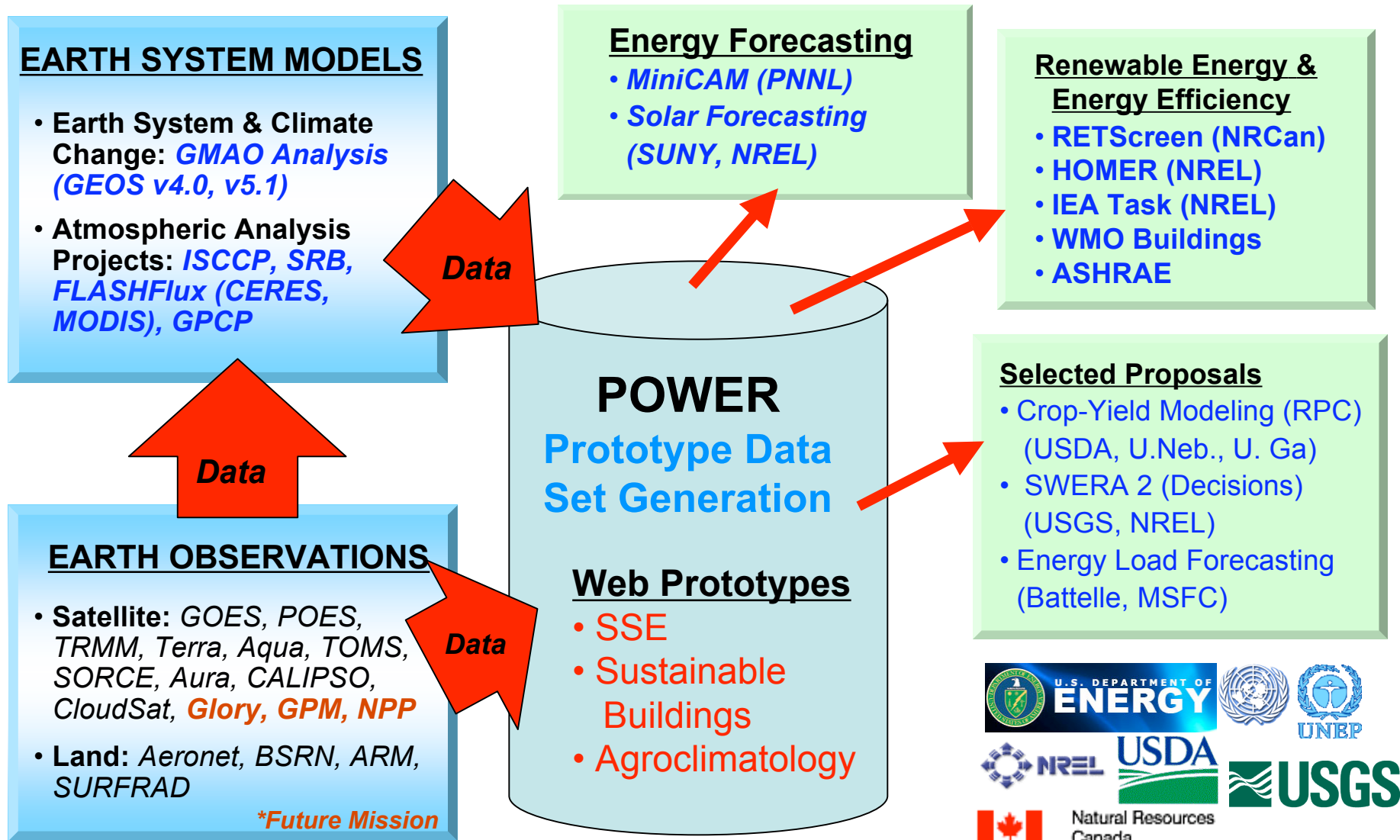
## *Global Monthly Irradiance for 2000*

Average Daily Solar Radiation for 2000 Jan





# POWER: Hub for Applications







# POWER Web Site

<http://power.larc.nasa.gov>



NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

[+ Visit NASA.gov](#)



## Prediction Of World Energy Resource

Surface meteorology and Solar Energy (SSE-release 5) : A renewable energy resource web site sponsored by NASA's Science Mission Directorate, Earth-Sun System Division, Applied Sciences Program

Earth Science for Society: Accelerating the realization of economic and societal benefits from Earth science, information, and technology ...

[Home](#) [SSE - Renewable Energy Parameters](#) [Sustainable Buildings Parameters](#) [Agroclimatology Parameters](#)

### Access Data

- [Data Format](#)
- [SSE - Renewable Energy](#)
- [Sustainable Buildings](#)
- [Agroclimatology](#)

### Documentation

- [About the POWER Project](#)
- [About SSE - Renewable Energy](#)
- [About Sustainable Buildings](#)
- [About Biomass Fuel- Agroclimatology](#)
- [Global Geometry/Resolution](#)
- [Parameter Accuracy/Validation](#)
- [Methodology of Satellite Inferred Parameters](#)
- [Power Publications](#)

### Related Links

- [Science Mission Directorate](#)
- [NASA's Applications Program](#)
- [Atmospheric Science Data Center](#)
- [Other Related Sites](#)

### Navigation and Help

- [Partners](#)
- [POWER Archive Statistics](#)
- [Release Notes](#)
- [Acknowledgments Please](#)
- [Join POWER Mailing List/ Submit Questions](#)
- [FAQs](#)

### Processing, archiving, and distributing solar insolation and meteorological parameters

- **SSE - RENEWABLE ENERGY:** Satellite-derived data supporting Renewable Energy Technologies (RET's).
  - Over 200 primary and derived meteorology and solar energy parameters
  - Monthly averaged parameters from July 1, 1983 through June 30, 1993
  - Global coverage on a 1° latitude by 1° longitude grid
  - Color plots on both global and regional scales
  - Solar energy data for 1195 ground sites
  - Data for the [RETScreen](#)® Renewable Energy Project Analysis Software
- **SUSTAINABLE BUILDINGS:** Satellite-derived data for the preliminary design of buildings and associated renewable-energy power systems.
  - Global coverage on a 1° latitude by 1° longitude grid
  - Twenty Two year monthly averaged temperatures, wind and solar radiation from July 1, 1983 through June 30, 2005
  - Daily averaged solar radiation from July 1983 through June 2005
  - Daily humidity and air temperatures for 1983 and December 2006
  - Temperature and relative humidity on 3-hourly time steps
  - Psychrometer chart and Global and/or regional plots
- **AGROCLIMATOLOGY:** Satellite-derived solar and meteorological data supporting agro-technology
  - Global coverage on a 1° latitude by 1° longitude grid
  - Daily total solar radiation from July 1983 through June 2005; and July, 2006 through current with one month delay
  - Daily averaged dew point and air temperatures from January 1983 through December 2006;
  - Daily averaged precipitation from January 1997 - current with two month delay



+NASA Privacy Statement, Disclaimer  
+ Freedom of Information Act



Responsible Official:  
**Paul W. Stackhouse, Jr., Ph.D.**  
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Last Updated: Wed May 09 2007 09:42:21  
GMT-0400 (EDT)

5/28/2008



# NASA SSE Release 6.0

- **22 Years**
- **New parameters**
- **Updated Solar algorithm**
- **Improved validation**
- **Increased accessibility including regions/time series**
- **Direct connection to 3 renewable energy DSS tools**

Surface meteorology and Solar Energy

http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?p.w.stack

Getting Started Latest Headlines

ATMOSPHERIC SCIENCE DATA CENTER

**Surface meteorology and Solar Energy**  
A renewable energy resource web site (release 6.0)  
sponsored by NASA's Earth Science Enterprise Program

**HIGHLIGHTS**

- over 200 satellite-derived meteorology and solar energy parameters
- monthly averaged from 22 years of data
- data tables for a particular location
- color plots on both global and regional scales
- global solar energy data for 1195 ground sites

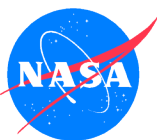
**Data Retrieval:**

- [Meteorology and Solar Energy](#)
- [Ground Site](#)
- [Renewable Software Application Inputs](#)
- [HOMER](#)
- [RETScreen](#)
- [SolarSizer](#)

**Supporting Documentation:**

- [Horizontal Grid for Input and Output](#)
- [Accuracy](#)
- [Methodology](#)
- [Parameters \(Units & Definition\)](#)
- [Frequently Asked Questions \(FAQ\)](#)
- [Related Web Sites](#)
- [Join SSE mailing list / Submit Questions](#)
- [Partners and Performance](#)

Responsible Officials: Data: [Paul W. Stackhouse, Jr., Ph.D.](#)  
[Charles H. Whitlock, Ph.D.](#)  
Archive: John M. Kusterer  
Site Administration/Help: NASA Langley [ASDC](#) User Services ([larc@eos.nasa.gov](mailto:larc@eos.nasa.gov))  
[Privacy Policy and Important Notices](#)  
Document generated on Thu May 1 16:11:40 EDT 2008

**Parameters for Sizing Battery or other Energy-storage Systems:****Equivalent Number Of NO-SUN Or BLACK Days (days)**

Lat 37 Lon -77	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1 day	0.96	0.95	0.95	0.93	0.91	0.92	0.95	0.89	0.92	0.96	0.94	0.96
3 day	2.61	2.38	2.46	2.66	2.47	1.89	2.16	2.39	2.07	2.37	2.46	2.44
7 day	5.08	4.51	4.53	3.95	4.48	3.33	3.53	3.58	3.61	4.43	3.58	4.11
14 day	7.15	6.14	4.08	5.31	6.77	4.35	3.98	4.95	4.57	5.39	4.74	7.12
21 day	6.19	8.35	5.00	5.24	7.35	4.93	5.12	6.02	3.70	7.40	5.82	8.44
Month	4.60	7.63	3.60	5.26	9.01	3.67	4.27	5.24	4.17	6.81	6.49	6.65

[Parameter Definition](#)**Parameters for Sizing Meteorology (Temperature):****Monthly Averaged Cooling Degree Days Above 18° C**

Lat 37 Lon -77	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Sum
22-year Average	0	0	4	22	86	189	257	224	130	34	5	1	952

[Parameter Definition](#)**Meteorology (Wind):****Monthly Averaged Wind Speed At 50 m Above The Surface Of The Earth (m/s)**

Lat 37 Lon -77	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
10-year Average	6.60	6.71	6.67	6.04	5.13	4.88	4.34	4.17	4.80	5.38	6.27	6.65	5.63

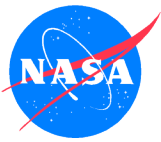
**Minimum And Maximum Difference From Monthly Averaged Wind Speed At 50 m (%)**

Lat 37 Lon -77	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Minimum	-13	-11	-14	-10	-13	-11	-10	-16	-8	-11	-8	-11	-11
Maximum	13	8	9	15	16	9	11	10	11	9	10	7	11

It is recommended that users of these wind data review the SSE [Methodology](#). The user may wish to correct for biases as well as local effects within the selected grid region.

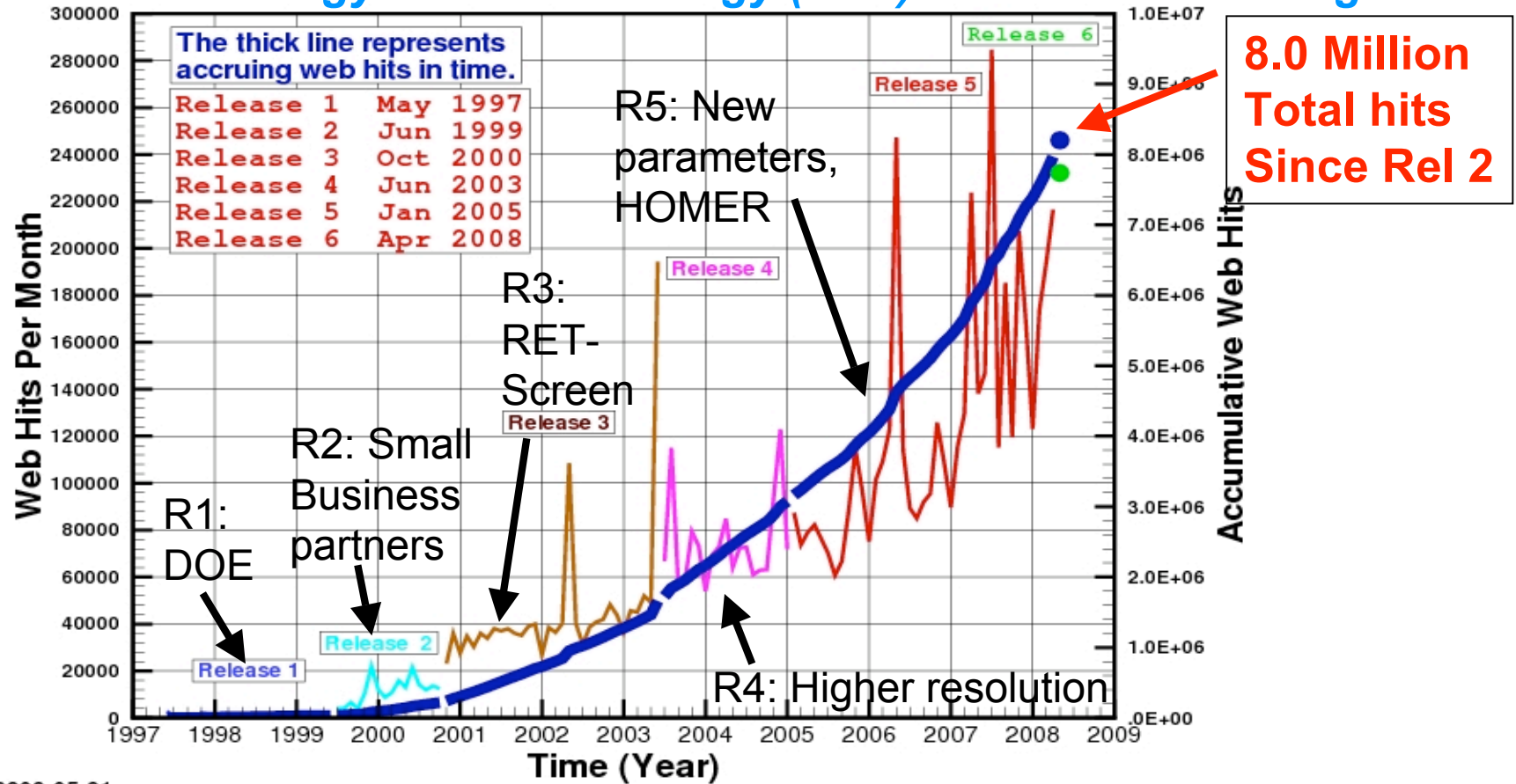
All height measurements are from the soil, water, or ice/snow surface instead of "effective" surface, which is usually taken to be near the tops of vegetated canopies.

[Parameter Definition](#)[Units Conversion Chart](#)

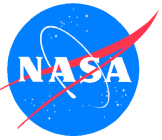


# POWER Sustains Growth of SSE Prototype and Web Interface

## Surface meteorology and Solar Energy (SSE) Web Interface Usage

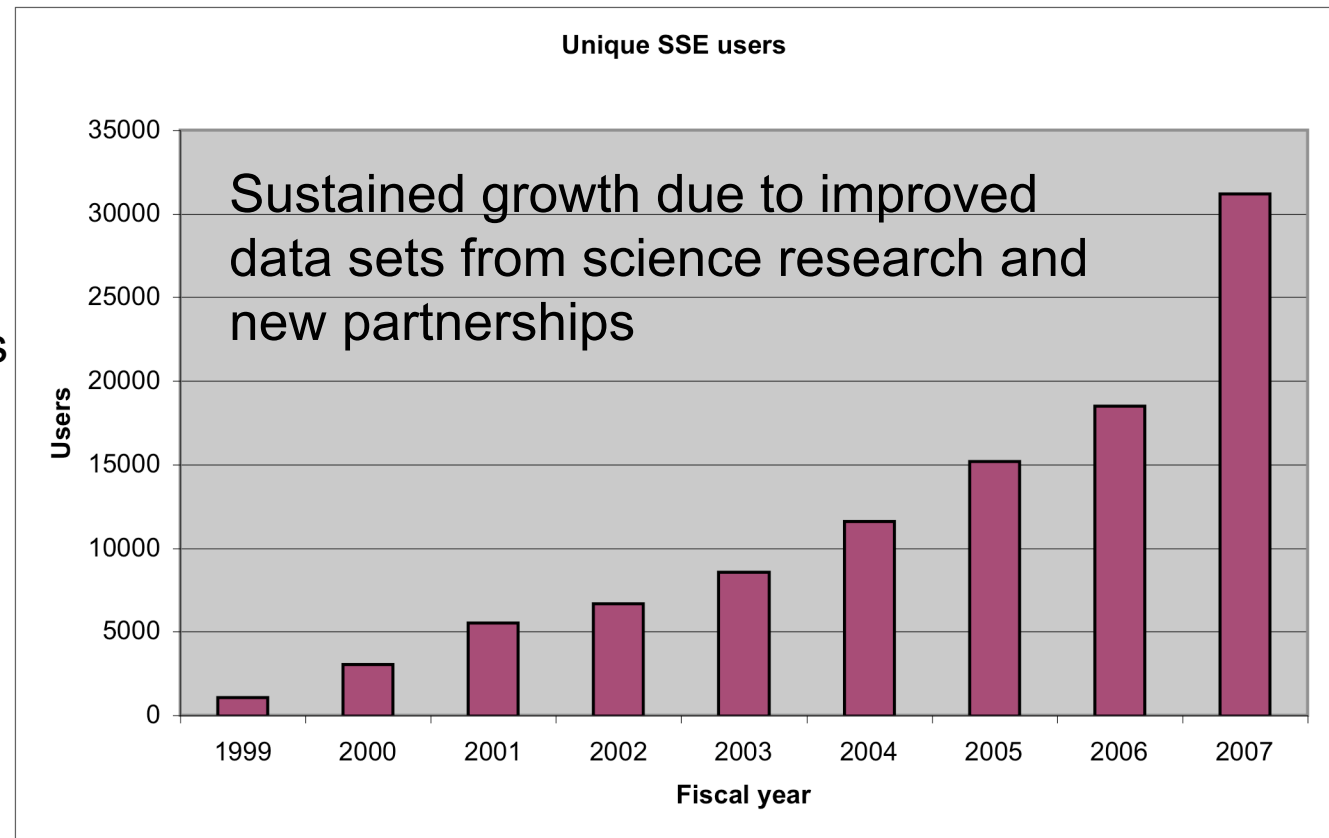


Monthly Averages	Release 1	Release 2	Release 3	Release 4	Release 5	Growth
Web Site Hits	1,278	12,533	35,000	74,500	121,180	95:1
Data Downloads	59	873	3,000	12,530	20,055	340:1



# POWER Sustains Growth of SSE Prototype and Web Interface

- Web site hosted by ASDC (no charge)
- Site responsible for 88% of all data requests
- Now over 30,000 unique users
- 116 different countries
- Business (72%), University (12%), Government/Military (7%), Private Citizens (7%), Organization (2%)



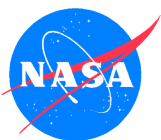
- Release 6: replaced solar data and Met data due to upgrades from SRB and GMAO science; now 22 years



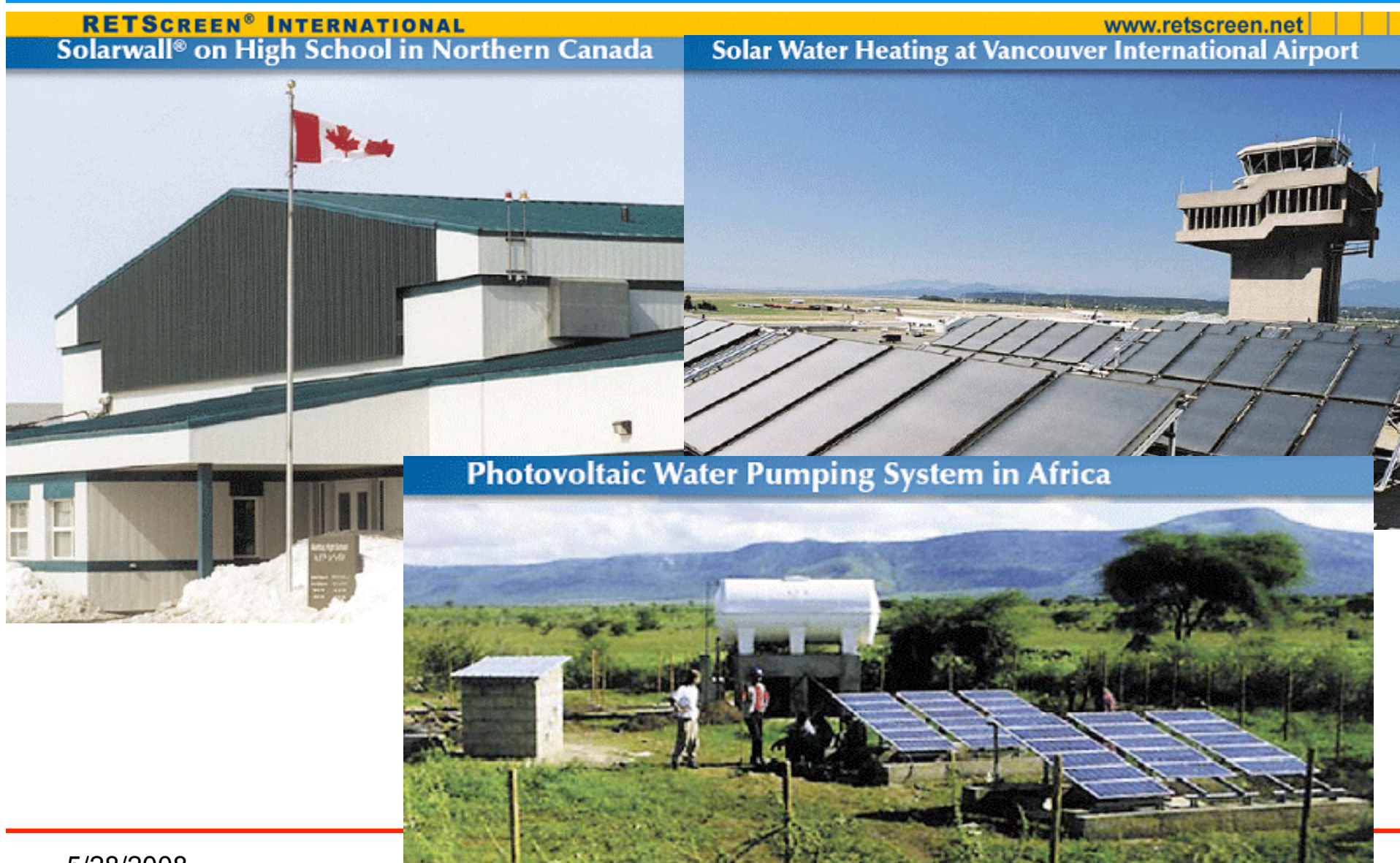


**RETScreen**  
www.retscreen.net

- Partners since 2000
- Variety of renewable energy projects
- Sponsored by Canada



# Projects Facilitated by RETScreen



5/28/2008

NASA LARC Research and Applied Science

10



## Five Step Start



Settings &  
Site Conditions

Enter data in shaded cells  
from top to bottom  
of each worksheet

Integrated Features

Climate  
Data

http://www.retscreen.net - RETScreen International

**RETScreen**

Country: China  
Province / State: Shanghai  
Climate data location: Shanghai

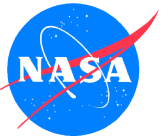
Latitude: °N 31.4  
Longitude: °E 121.5  
Elevation: m 4.0  
Heating design temperature: °C -0.4  
Cooling design temperature: °C 33.2  
Earth temperature amplitude: °C 14.7

Source: Ground, Ground, NASA, Ground, Ground, NASA, Ground, Ground

	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°F	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
Jan	43.2	73.0%	2.61	102.5	3.1	5.4	406	0
Feb	49.2	70.4%	3.08	102.4	3.0	6.4	330	0
Mar	49.1	75.1%	3.54	102.0	3.3	9.5	264	0
Apr	59.0	73.9%	4.46	101.5	3.2	14.3	90	150
May	68.9	74.6%	5.05	101.0	3.2	18.9	0	326
Jun	74.8	81.5%	4.64	100.6	3.2	22.8	0	414
Jul	82.6	80.0%	5.15	100.4	3.3	26.6	0	561
Aug	81.9	81.3%	4.82	100.5	3.5	26.6	0	549
Sep	75.9	76.6%	4.09	101.1	3.4	23.1	0	432
Oct	66.7	73.8%	3.47	101.8	2.9	18.4	0	288
Nov	56.3	73.0%	2.91	102.3	3.0	13.2	135	105
Dec	46.0	71.7%	2.56	102.6	2.9	7.7	316	0
Annual	62.2	75.4%	3.87	101.6	3.2	16.1	1,541	2,825
Source	Ground	Ground	NASA	NASA	Ground	NASA	Ground	Ground

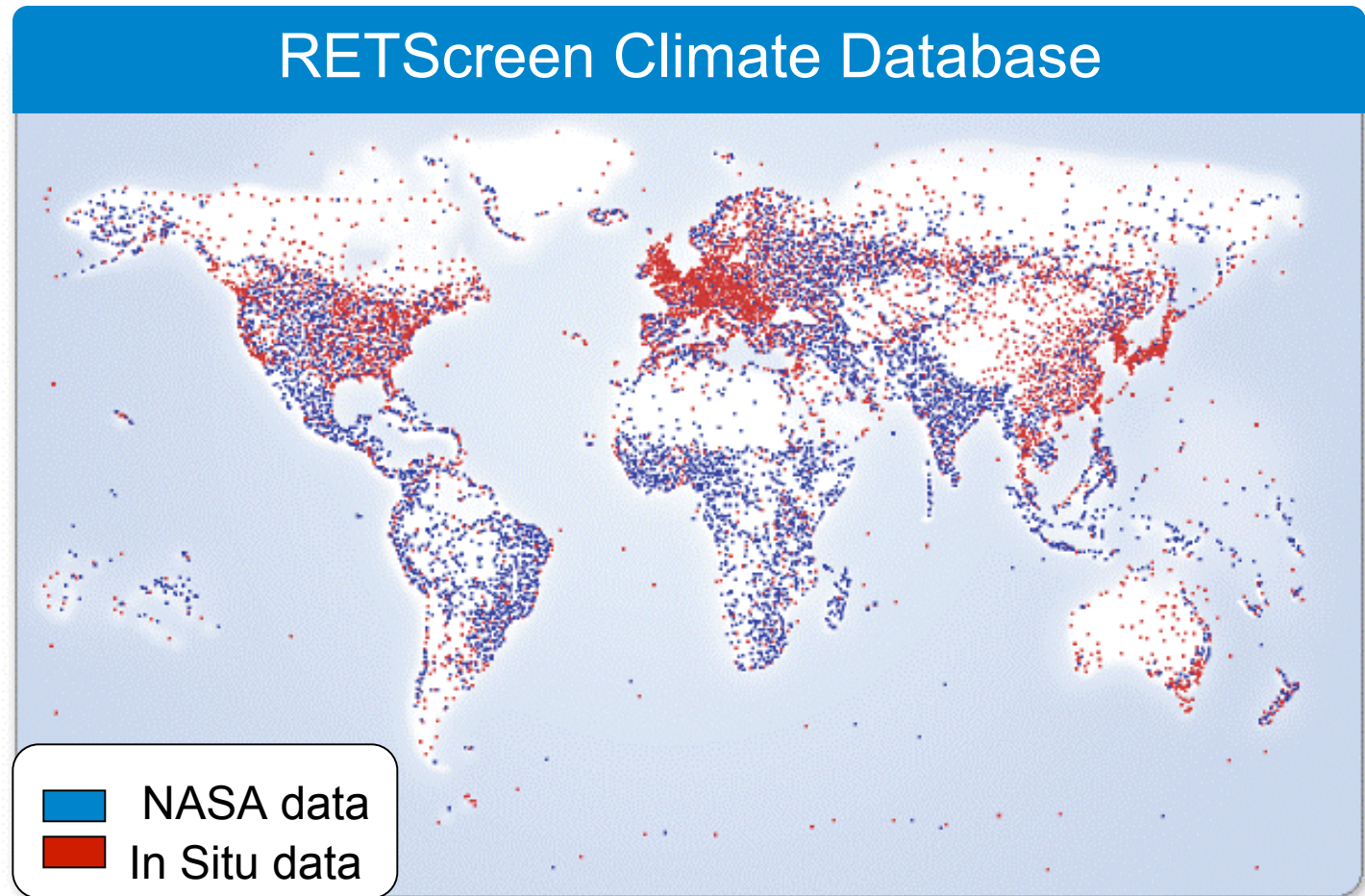
Measured at: m 10 0

- Engineering Textbook
- Case Studies
- Marketplace & Maps



# RETScreen's Reliance on POWER Data

- Clean energy project analysis software
- Funded by Canada (NRCan)
- Direct query of SSE data
- 155,100 users
- 222 countries
- 1000 new users every week
- Release 4: 26 languages



Points represent world's cities (~10,000). Red have in situ observations. Blue defer to NASA LaRC data sets (~5,000). Data for locations between points are found through a direct link to SSE.



# RETScreen's and NASA's Impact

Worldwide Performance Indicators	Present Impact 1998 – 2004 <sup>1</sup>	Future Impact 1998 – 2012 <sup>1</sup>	Future Impact Next 30 Years <sup>2</sup>
User Savings	\$600 million	\$7.9 billion	~\$200 Billion
Installed Capacity	1,000 MW	24 GW	-
Installed Value	\$1,800 million	41 billion	~\$1 Trillion
GHG Reduction	630 kT CO <sub>2</sub> /yr	20MT CO <sub>2</sub> /yr	-

On the value of NASA's contribution, Greg Leng, Directeur RETScreen Project:  
**NASA would have an impact on every single project.....**

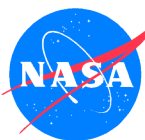
NASA is highly regarded by our users because of the contribution you have made to clean energy deployment via the partnership with RETScreen.....

Source: <sup>1</sup>RETScreen International: Results and Impacts 1996-2012;

<sup>2</sup>Personal Communication from RETScreen Directeur, Greg Leng

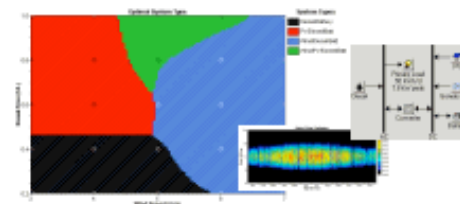
Currencies in Canadian dollars: \$1 CAD ~ \$.72 US, May 12, 2004





# HOMER

THE OPTIMIZATION MODEL FOR DISTRIBUTED POWER



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## About HOMER

### Overview

[User Interface](#)  
[Version History](#)  
[User Testimonials](#)  
[Ask Tom \(FAQs\)](#)

## Downloads

[Software](#)  
[Sample Files](#)  
[Getting Started Guide](#)  
(PDF File, 720 kB)  
[Brochure \(English\)](#)  
(PDF File, 964 kB)  
[Brochure \(Spanish\)](#)  
(PDF File, 1.3 MB)  
[Bibliography](#)  
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[Webcast Materials](#)  
May 16, 2006

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23150 people have  
downloaded HOMER from  
190 countries...

[Security & Privacy](#)

HOMER is a computer model that simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone, and distributed generation (DG) applications. HOMER's optimization and sensitivity analysis algorithms allow you to evaluate the economic and technical feasibility of a large number of technology options and to account for variation in technology costs and energy resource availability. HOMER models both conventional and renewable energy technologies:

### Power sources:

- solar photovoltaic (PV)
- wind turbine
- run-of-river hydro power
- generator: diesel, gasoline, biogas, alternative and custom fuels, cofired
- electric utility grid
- microturbine
- fuel cell

### Storage:

- battery bank
- hydrogen

### Loads:

- daily profiles with seasonal variation
- deferrable (water pumping, refrigeration)
- thermal (space heating, crop drying)
- efficiency measures

**You can now subscribe to the HOMER newsletter. [Click here for details](#)**

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# HOMER Example Project

*The island of Tac, Region de los Lagos, Chile*

An optimization analysis using HOMER showed that a wind-diesel system with battery storage would most cost-effectively supply the energy required by the island. HOMER's sensitivity analysis capability helped the team assess the impact of fuel price on the least-cost system design.

## Rural Electrification in the Chiloe Islands

**T**he Chiloe Islands are located off the Pacific Coast of Southern Chile. Of the more than 40 islands in the group, 32 are too far from the coast to be connected to the mainland electric grid and either have no access to electricity, or intermittent access provided by diesel generators. The islands range in size from 12 to 450 homes, with projected loads ranging from 17 to 1004 kWh/day. Economic activity on the islands includes farming, animal husbandry, and fishing. NREL, through a cooperative agreement between the governments of Chile and the United States, worked with a team of local and international experts to implement a pilot hybrid power system on Isla Tac, one of the Chiloe islands. The team conducted economic, loads, and renewable resource studies and used the results from those studies as inputs to HOMER.

Ian Baring-Gould



*The Isla Tac Power system provides power to the islands' 82 families.*

The team also used two other NREL models: ViPQR to determine electric distribution mini-grid costs, and Hybrid2 to finalize the design of the hybrid power system. This work helped lead to a \$40 million multilateral development bank loan to provide rural electrification projects, including replication of this pilot project, across the entire Chiloe island region.



# NASA/HOMER (NREL) Partnership

- **NREL HOMER Micropower Optimization Model**

- *HOMER is a computer model that simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone, and distributed generation (DG) applications.*
- Highlighted in CCSP SAP 5.1 as a case study in decision support using Earth observations
- NASA and other Earth observation data sources critical to its success (e.g., solar from LaRC; AOD from GSFC GOCART model, MODIS, MISR, TOMS; Digital land cover from NASA & USGS)
- Used extensively around the world for determining the optimal mix of power technologies for meeting specified load conditions at specified locations
- *“Best hourly assessment tool for hybrid renewable electric generation systems in the world - bar none.”*

Dr. Jan F. Kreider

Building Systems Program, University of Colorado, January 2008

- **HOMER automatically accesses and inputs the POWER SSE data for the specific location that the model is analyzing.**

- Collaboration with ROSES-funded SWERA II task at USGS EROS data center.



## HOMER

THE OPTIMIZATION MODEL FOR DISTRIBUTED POWER



# HOMER's Reliance on NASA

- Lead Dr. Peter Lilienthal, NREL, notes most users now use NASA's solar irradiance data set.
- POWER/SSE is showing increasing HOMER related data requests



## HOMER

THE OPTIMIZATION MODEL FOR DISTRIBUTED POWER

Total Users	20777
Countries	189
Country	Users
USA	6074
Canada	1250
Australia	1034
Spain	993

Organization Type	Users
Academic or research	7687
For-profit corporation	3193
Government	1441
Individual	6971
NGO	890
Other	551

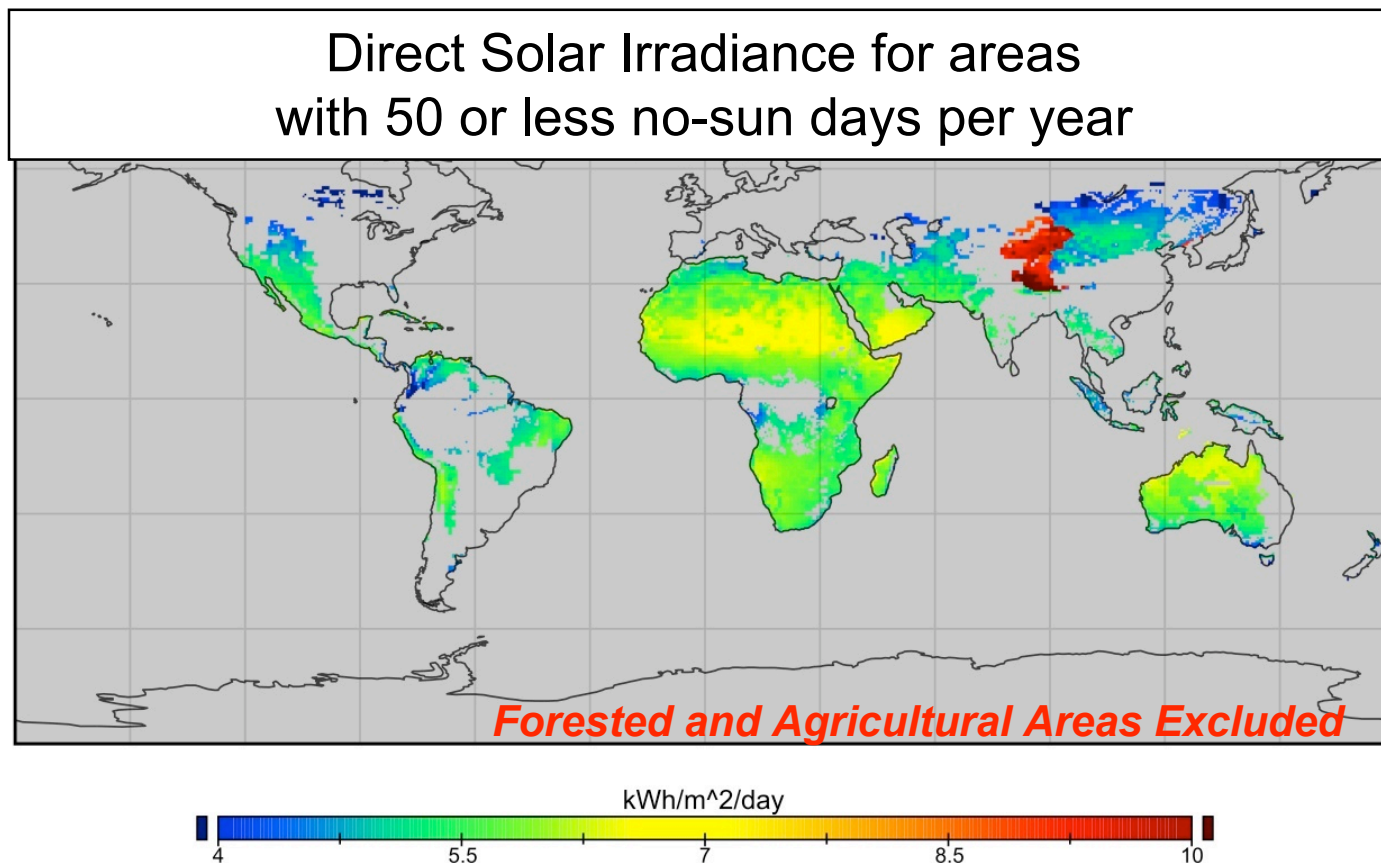
***Future: HOMER actively being modified by NREL for regional distributed power generation Assessment => perfectly suited for NASA coarse scale data sets***





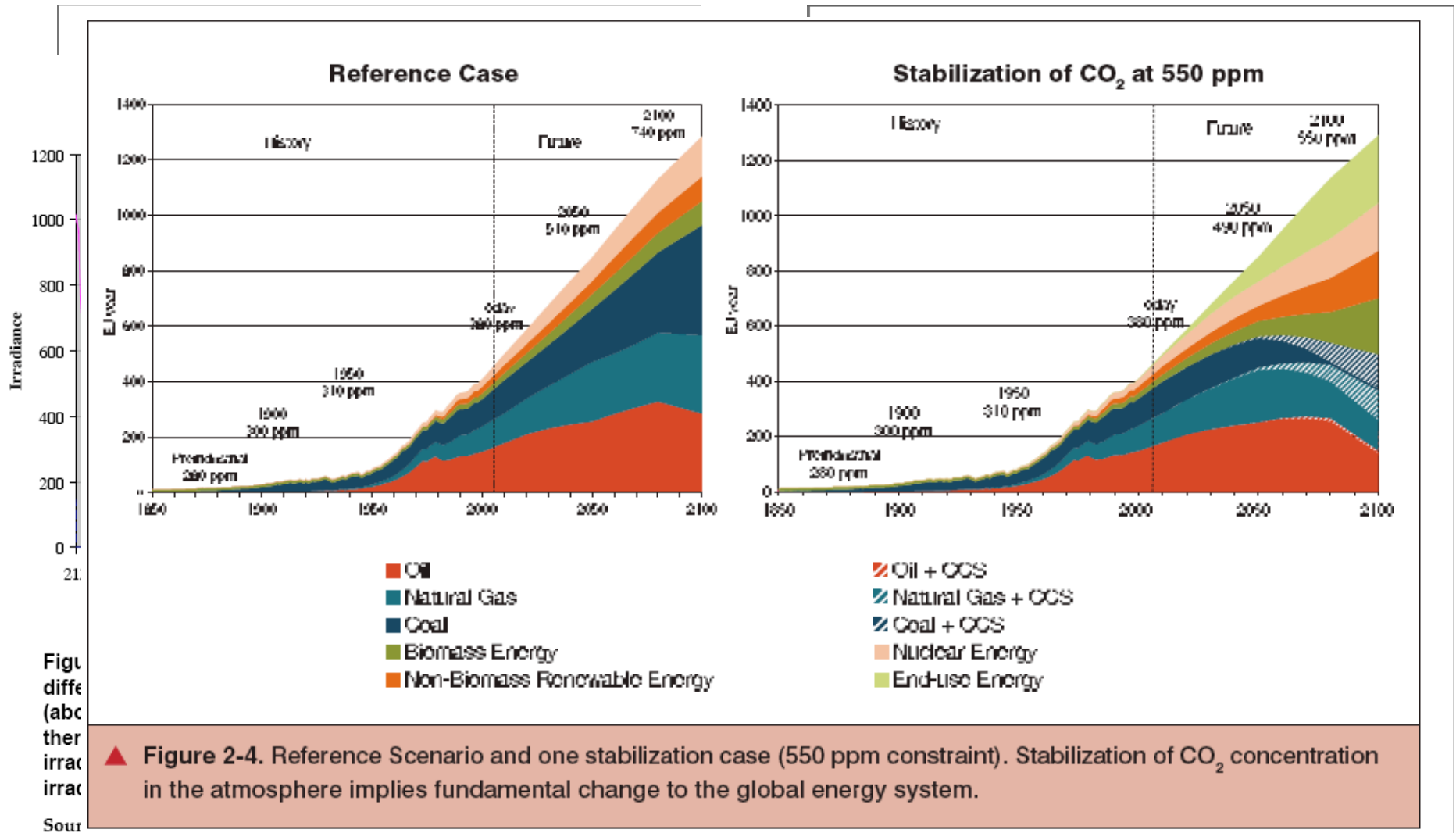
# PNNL Integrated Assessment Model Initialization with NASA/POWER Data

PNNL/Joint Global Change Research Center uses NASA  
POWER data sets for initiation of MiniCam 50-year energy  
market forecasts for policy planning





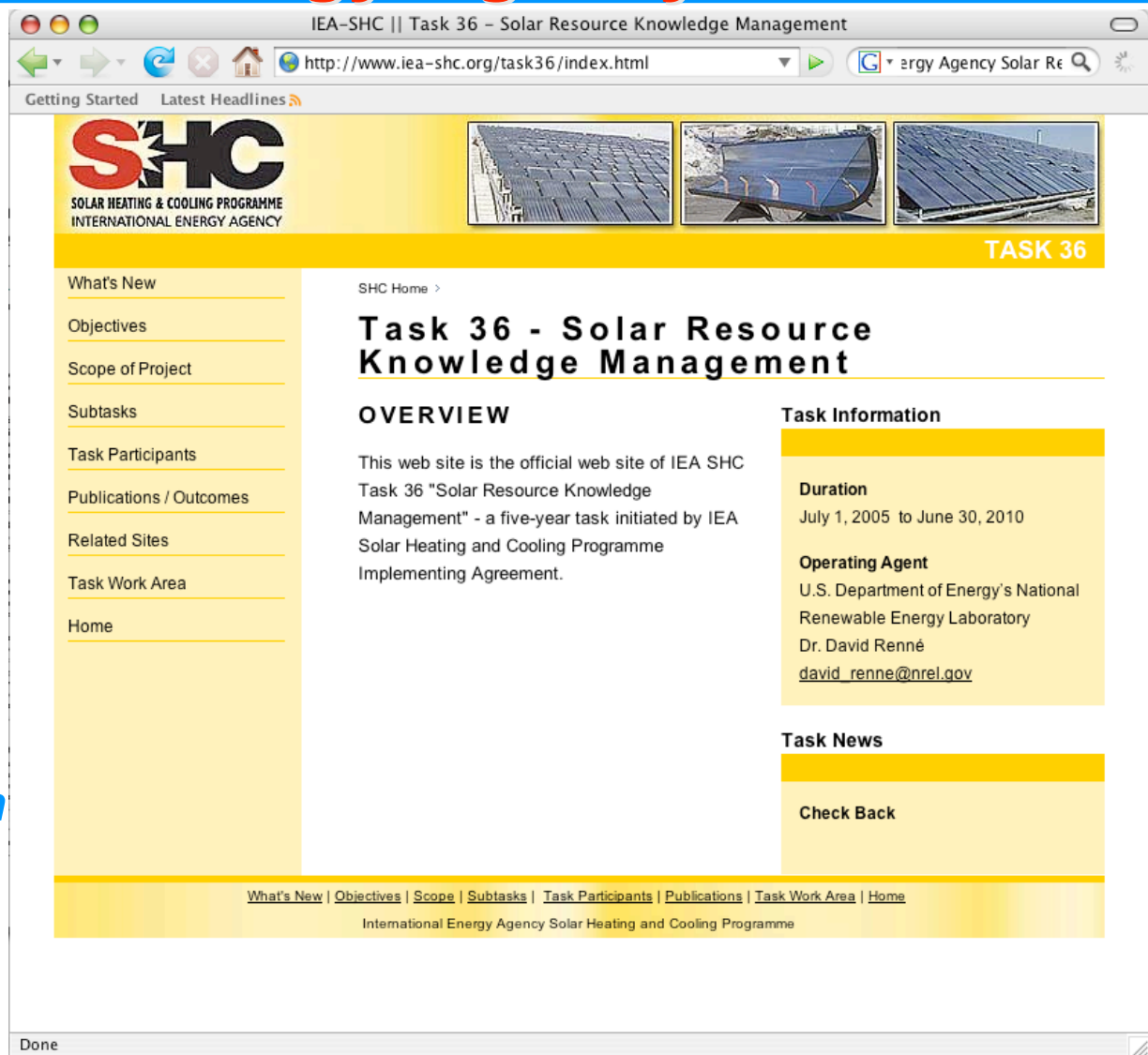
# PNNL's Assessment Results





# NASA POWER Contributes to International Energy Agency Task

- *International collaboration representing >8 nations; >15 Organizations*
- *5 Year Task*
- *NREL led*
- *NASA/POWER contributing expertise on solar resource estimation and validation, user and interface information, data sets and research (results from GEWEX SRB and GEWEX Radiative Flux Assessment)*



The screenshot shows a web browser window with the address bar displaying "http://www.iea-shc.org/task36/index.html". The page title is "IEA-SHC || Task 36 - Solar Resource Knowledge Management". The website has a yellow header with the "SHC" logo and the text "SOLAR HEATING & COOLING PROGRAMME INTERNATIONAL ENERGY AGENCY". Below the header, there are three small images showing solar panels. The main content area is titled "Task 36 - Solar Resource Knowledge Management" and includes an "OVERVIEW" section. On the right, there is a "Task Information" box with details about the task's duration and operating agent. At the bottom, there is a "Task News" section with a "Check Back" button. A sidebar on the left lists various navigation links.

IEA-SHC || Task 36 - Solar Resource Knowledge Management

http://www.iea-shc.org/task36/index.html

Getting Started Latest Headlines

**SHC**  
SOLAR HEATING & COOLING PROGRAMME  
INTERNATIONAL ENERGY AGENCY

**TASK 36**

What's New  
Objectives  
Scope of Project  
Subtasks  
Task Participants  
Publications / Outcomes  
Related Sites  
Task Work Area  
Home

SHC Home >

## Task 36 - Solar Resource Knowledge Management

### OVERVIEW

This web site is the official web site of IEA SHC Task 36 "Solar Resource Knowledge Management" - a five-year task initiated by IEA Solar Heating and Cooling Programme Implementing Agreement.

#### Task Information

**Duration**  
July 1, 2005 to June 30, 2010

**Operating Agent**  
U.S. Department of Energy's National Renewable Energy Laboratory  
Dr. David Renné  
[david\\_renne@nrel.gov](mailto:david_renne@nrel.gov)

#### Task News

**Check Back**

[What's New](#) | [Objectives](#) | [Scope](#) | [Subtasks](#) | [Task Participants](#) | [Publications](#) | [Task Work Area](#) | [Home](#)

International Energy Agency Solar Heating and Cooling Programme

Done



# NASA Energy Program Contributions to GEO

- *Core member of GEO energy community of practice*
  - Applied Sciences-funded activities contribute directly to GEO work plan tasks EN06-04, EN07-01, EN07-03
  - IEA activity, leveraged with ESA partnership, provided first GEO energy early achievement project “Solar Information for Developing Countries”
  - One of principal authors of GEO Energy Strategic Plan, which closely mirrors Applied Sciences Program plan
  - Lead for **CEOS** Energy SBA activities (GEO-CEOS remapping activities)
  - Energy articles published in GEO summit publication (two with NASA involvement)



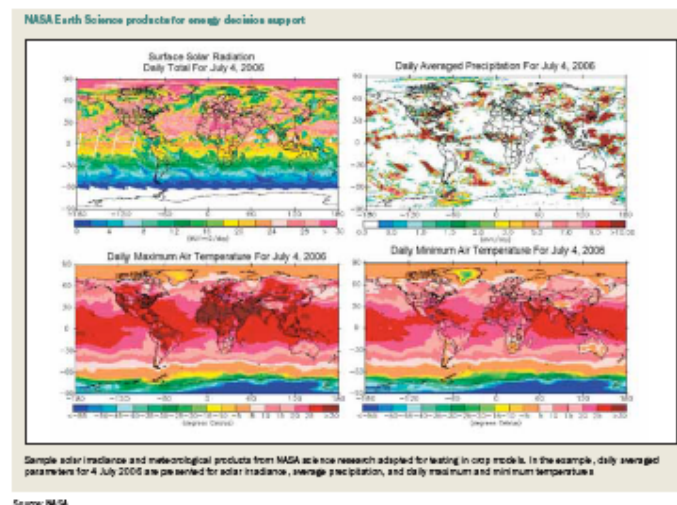
## Informing decision making in the energy sector using NASA spaceborne observations and model predictions

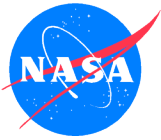
Richard S. Eckman and Paul W. Stackhouse, Jr, NASA Langley Research Center

Adapting global sets of spaceborne observations — often made for diverse research purposes — to enhance end-user decision making remains a challenge for the Global Earth Observation Systems of Systems (GEOSS). The US National Aeronautics and Space Administration (NASA) Applied Sciences Program (the Program) seeks to identify innovative uses for NASA-derived spaceborne observations and model predictions and connect with end users to enhance their ability to make management and policy decisions. The Applied Sciences Program's Energy Management application extends NASA Earth science research results to improve decisions and assessments for energy production and energy efficiency, by interacting with partners to benchmark NASA research datasets derived from the analysis of historic and current observations and models to meet energy sector needs. These partners are other government agencies (both domestic and international), academia, professional organizations and the

International Satellite Cloud Climatology Project (ISCCP), Surface Radiation Budget (SRB), Global Modeling and Assimilation Office (GMAO), Goddard Earth Observing System (GEOS) meteorological analysis model, and Langley Research Center FLASHFlux project providing near-real time surface radiative flux.

RETScreen (www.retscreen.net) is a clean energy decision support system, developed by NRC's CANMET Energy Technology Centre, which enables end users to better assess the feasibility of renewable energy and energy efficiency projects, their costs, and greenhouse gas mitigation benefits. Surface solar energy measurements available from ground observations are often sparse or unavailable in the developing world. NASA's satellite-derived global observations and





# GEOSS: 1st Energy Demonstration

(hosted by Ecole des Mines de Paris)

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## Results of your request

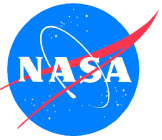
### NASA SSE - Surface meteorology and Solar Energy National Aeronautics and Space Administration (NASA, USA)

Site latitude (positive means North)	45.390
Site longitude (positive means East)	-75.910
Beginning date	1983-07-01
End date	1993-01-01
Irradiance	Daily mean of irradiance in W/m2 (-999 if no data)
Irradiation	Daily irradiation in Wh/m2 (-999 if no data)

Daily means of Irradiances in W/m2 from  
NASA SSE

	Month	Day	Irradiance	Irradiation
1983	7	1	170	4080
1983	7	2	172	4130
1983	7	3	195	4680
1983	7	4	246	5920
1983	7	5	142	3410
1983	7	6	305	7320
1983	7	7	252	6050
1983	7	8	102	2470
1983	7	9	348	8360
1983	7	10	350	8410
1983	7	11	125	3010
1983	7	12	277	6670
1983	7	13	320	7700
1983	7	14	324	7780
1983	7	15	260	6250
1983	7	16	317	7620
1983	7	17	322	7730
1983	7	18	298	7170
1983	7	19	243	5840
1983	7	20	321	7720





# SWERA 2: Renewable Resources for Developing Nations

- **USGS-led ROSES Proposal**

- **Data archive, User Interface at UNEP GRiD/USGS**

- **NASA/POWER role: supply global data parameters**



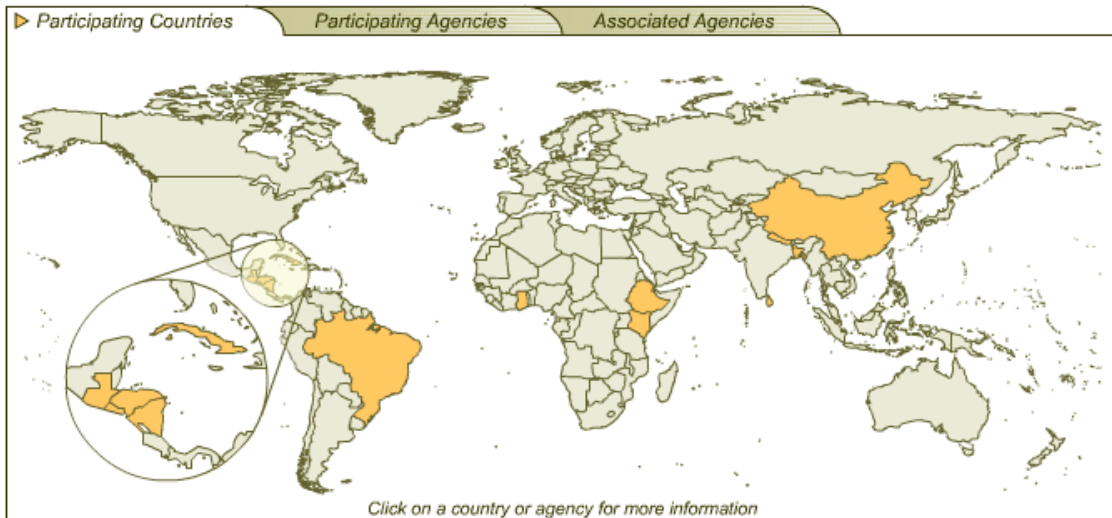
## Solar and Wind Energy Resource Assessment

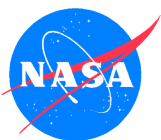


### Welcome To SWERA

The **SWERA** website provides information about solar and wind energy resources in thirteen partner countries around the world. Products held in the SWERA archive include data on wind and solar energy potential, plus detailed country energy analyses. To learn more about renewable energy in each country or the partner agencies, click on the map or the menu. SWERA is a UNEP (United Nations Environment Programme) project with co-financing from GEF. The goal is to provide solar and wind energy assessments to potential investors and the public to promote more effective use of alternative energy resources.

Now with the completion of the successful pilot project, SWERA is being expanded into a full Programme offering resource information and mapping tools across the spectrum of renewable energy sources. All information and tools can be found in one on-line location with a common user interface... click [here](#) for more details.





# SWERA 2: Guatemala Demonstration

## Maps - Central America



Guatemala

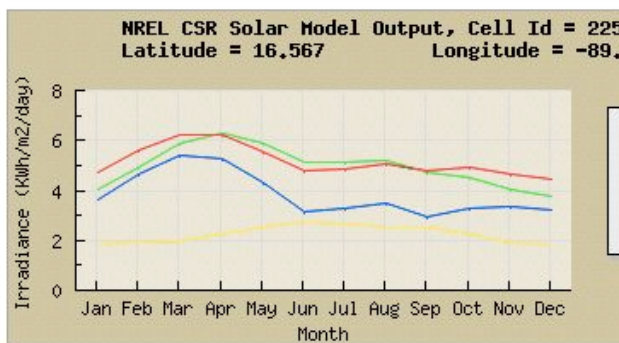
Choose an Action:

- ☐ Browse map  
☒ Query time series

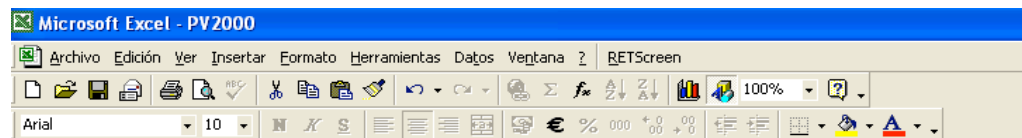
Select Layers to Display:

(Press CTRL for multiple selection)

- Land Use  
40km Solar Concentrators (KWh/m2/day)  
40km Solar PV (KWh/m2/day)  
40km CSR Plots



Data (KWh/m2/day)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature	21.4	21.8	23.0	24.9	25.2	25.0	24.0	24.2	24.3	24.2	23.0	21.4
Direct	3.6	4.7	5.4	5.3	4.3	3.2	3.3	3.5	2.9	2.9	2.9	2.9
Global	4.0	5.0	5.9	6.3	5.9	5.1	5.2	5.2	4.7	4.7	4.7	4.7
Latitude Tilt	4.7	5.6	6.2	6.2	5.5	4.8	4.8	5.0	4.8	4.8	4.8	4.8
Diffuse	1.9	1.9	2.0	2.3	2.6	2.7	2.7	2.5	2.5	2.5	2.5	2.5



### RETScreen® Solar Resource and System Load Calculation - Photovoltaic Project

Site Latitude and PV Array Orientation	Estimate	Notes/Range
Nearest location for weather data	Neuquen A	Weather Database
Latitude of project location	15.8	-90.0 to 90.0
PV array tracking mode	Fixed	
Slope of PV array	55.0	0.0 to 90.0
Azimuth of PV array	180.0	0.0 to 180.0

### Monthly Inputs

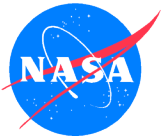
Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average daily radiation in plane of PV array (kWh/m²/d)	Monthly solar fraction (%)
January	1.00	4.30	20.5	1.53	13%
February	1.00	5.00	21.1	1.95	17%
March	1.00	5.80	22.5	2.94	25%
April	1.00	6.30	24.6	4.19	36%
May	1.00	5.90	24.6	4.65	40%
June	1.00	5.30	24.2	4.43	38%
July	1.00	5.30	23.0	4.32	37%
August	1.00	5.40	23.1	3.94	34%
September	1.00	4.90	23.2	2.98	26%
October	1.00	4.60	22.6	2.13	18%
November	1.00	4.30	22.0	1.58	13%
December	1.00	3.90	21.2	1.48	13%

	Annual	Season of use
Solar radiation (horizontal)	MWh/m² 1.86	1.86
Solar radiation (tilted surface)	MWh/m² 1.10	1.10
Average temperature	°C 22.7	22.7

Load Characteristics	Estimate	Notes/Range
Application type	Off-grid	
Use detailed load calculator?	Yes	

Description	AC/DC	Solar-load	Load	Hours of use	Days of use
Intro					
Energy Model					
Solar Resource & System Load					
Cost Analysis					
GHG Analysis					
Financial Summary					

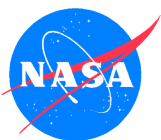




# Potential Future Energy Applications

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- ***Advanced Long-term Solar Mapping (NREL)***
  - Earth System Science models (ESSM): GMAO MERRA, GOCART
  - Satellite-based: ISCCP B1U (w/ 8km pixels), TOVS-TOMS
- ***Solar Energy Forecasting (NREL, SUNY)***
  - Earth System Science models (ESSM): GMAO forecasts
  - Satellite-based: FLASHFlux (for validation)
- ***Building Targeting and Monitoring (NRCan)***
  - ESSM: GMAO operational assimilation
  - Satellite-based: FLASHFlux
- ***Building data sets for design (DOE, ASHRAE)***
  - ESSM: GMAO GEOS-4, MERRA, GOCART
  - Satellite-based: GEWEX SRB
- ***Load Forecasting (Battelle, Ventyx)***
  - ESSM: GMAO operational assimilation, forecasts; SPORT



# Advanced Long-term Solar Mapping

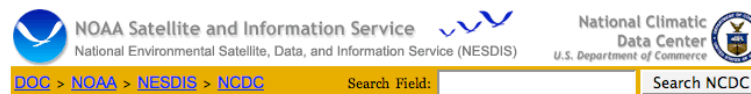
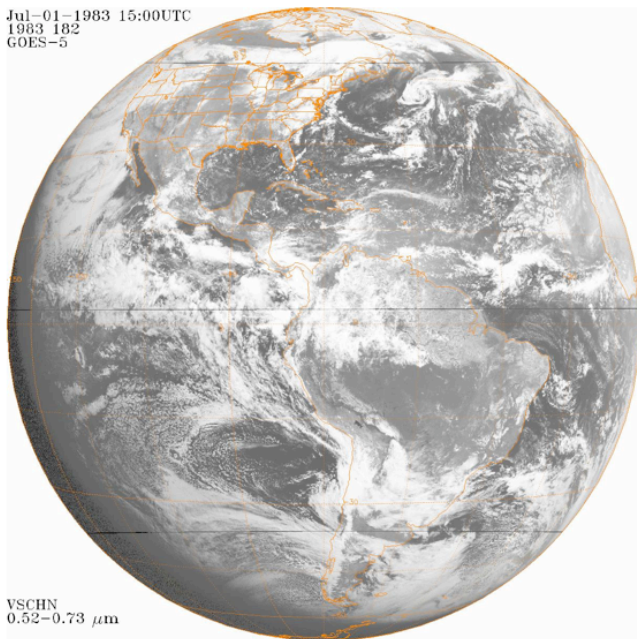
*Using newly archived ISCCP B1U and latest long-term H<sub>2</sub>O, O<sub>3</sub>, aerosol information develop long-term solar maps at high resolution*



[Satellite Data](#) > [GIBBS](#) > [1983](#) > [July 01](#)

July 01, 1983 15:00 UTC  
Channel: Visible (~0.65um)  
Satellite: GOES-5

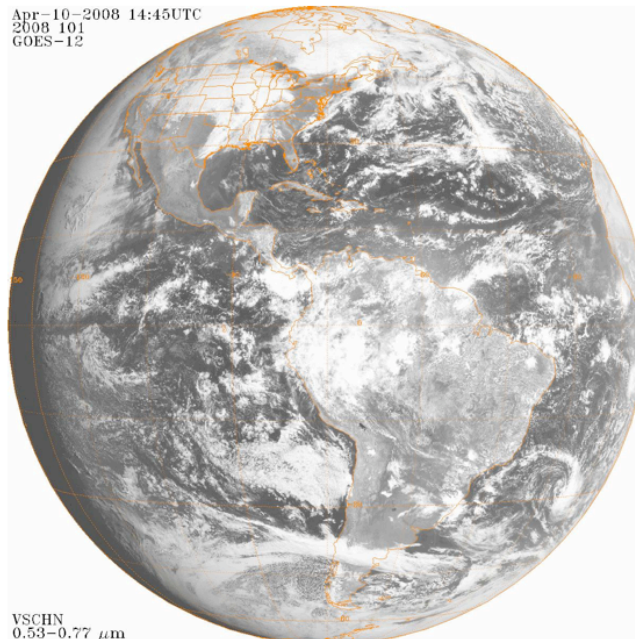
Jul-01-1983 15:00UTC  
1983 182  
GOES-5

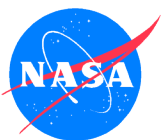


[Satellite Data](#) > [GIBBS](#) > [2008](#) > [April 10](#)

April 10, 2008 15:00 UTC  
Channel: Visible (~0.65um)  
Satellite: GOES-12

Apr-10-2008 14:45UTC  
2008 101  
GOES-12

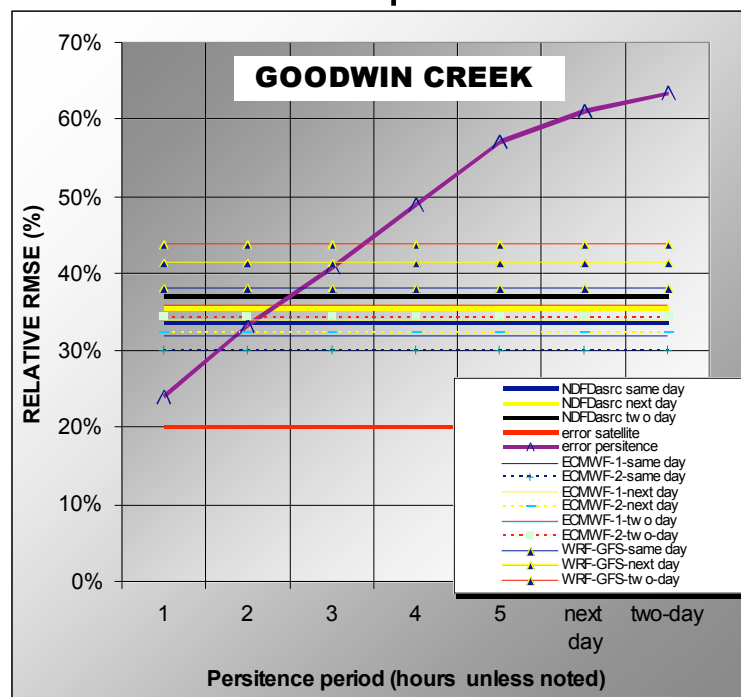




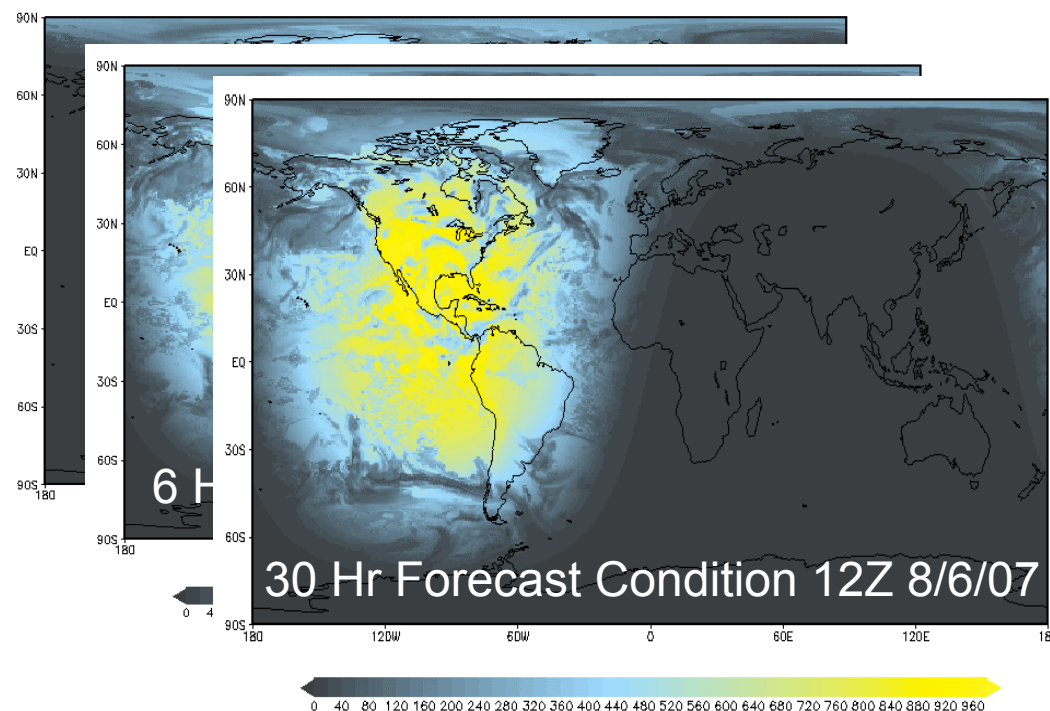
# Benchmarking Solar Forecasts

*Vital for assessing potential large scale PV and/or CSP production when integrating into traditional power grid*

## Multi-Model Solar Irradiance Comparison



## GMAO Solar Irradiance Forecast



Draft courtesy Perez, SUNY



# Building Monitoring and Targeting

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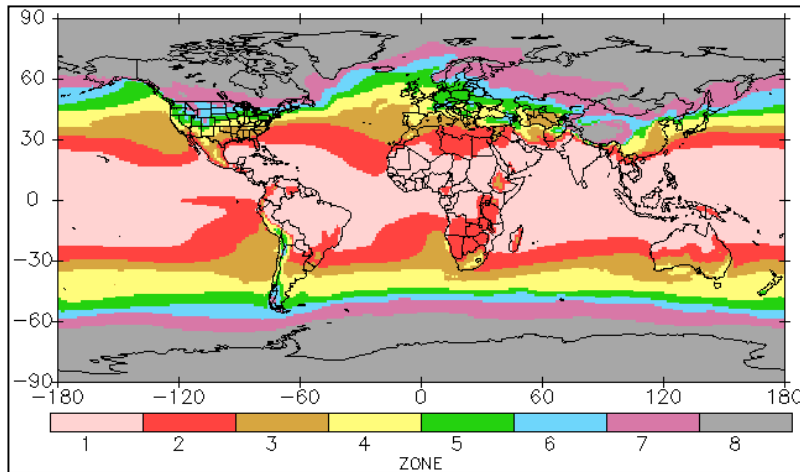
- **Monitoring and Targeting:** gaining and maintaining control over energy consumption through measurement and analysis followed by well-directed actions.
  - *Comparison between energy consumption and influencing factors such as weather; establish and evaluate consumption targets*
  - *Purpose: energy cost savings for budgeting, evaluation of energy efficiency upgrades, product/service costing*
- **NRCAN CETR RETScreen leading effort for newly formed building monitoring and targeting program**
  - Need global near-real time (within 1 month) solar and meteorological (i.e. heating degree day) data sets
  - FLASHFlux with operational GMAO assimilation perfectly suited by providing daily and monthly estimates of parameters



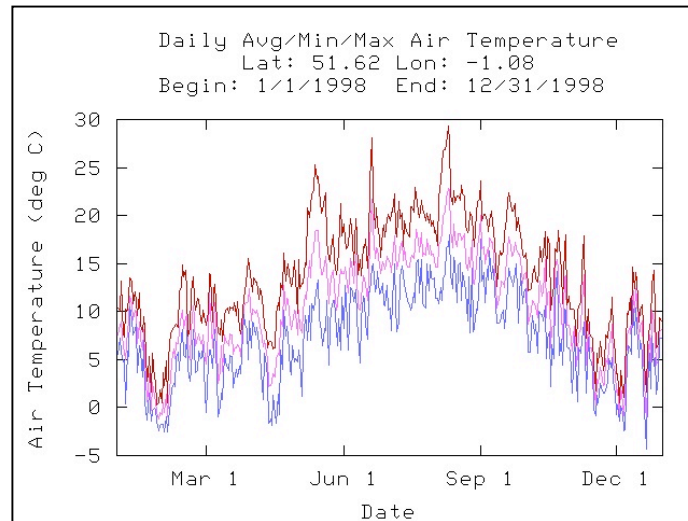


# Long-term Climate Information For Building Design

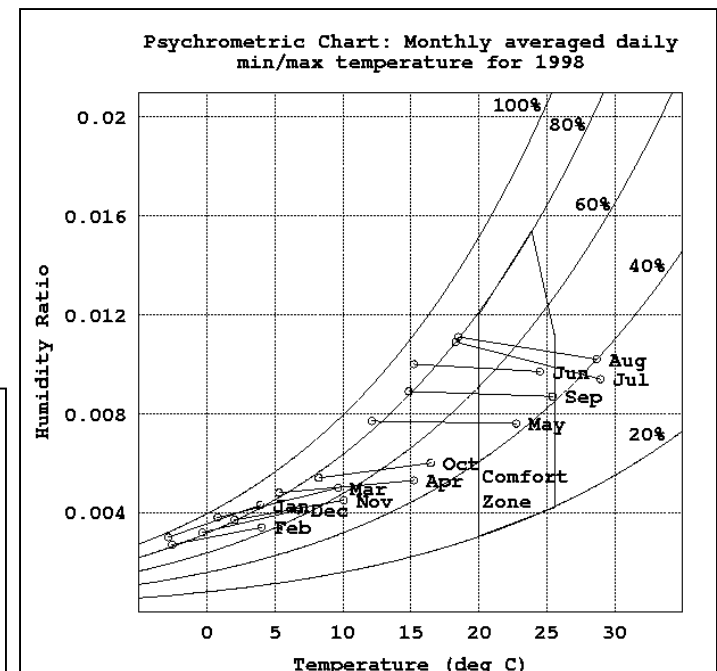
## Global Building Design Climate Zones (with ASHRAE and DOE)



## Location Specific Daily/Monthly Averaged Climate Information



## Location Specific Traditional Architectural Comfort Zone Design Charts (with AIA)



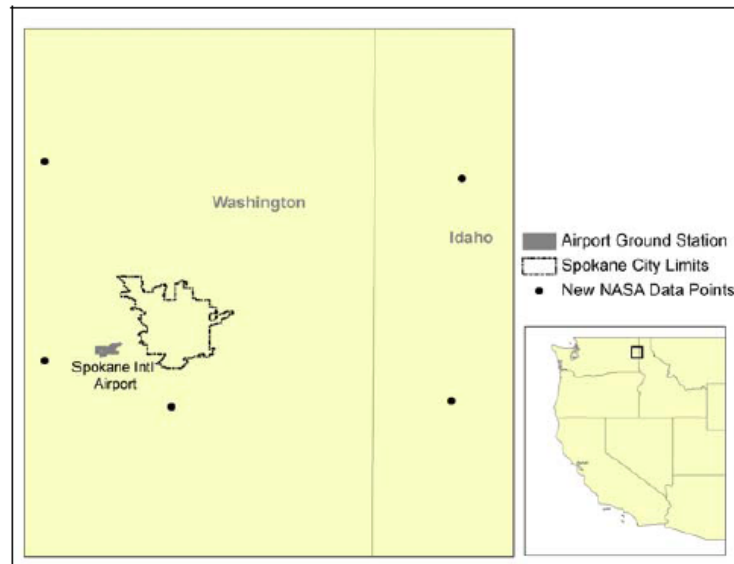
**30 Years Needed!**



# Energy Load Forecasting

*ROSES proposal w/ E  
evaluation NASA long  
and high resolution*

Spokane, Washington



*Courtesy E. Zel*

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Latest News

Tuesday, Apr. 8 2008

**Project Explores Using NASA Earth Science Data for Enhanced Utility Load Forecasting**

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COLUMBUS, Ohio, April 8, 2008 /PRNewswire-USNewswire via COMTEX/ — Battelle leads project that applies weather-related data to energy usage

NASA and Battelle plan to save consumers money on their electric and gas bills. Using high-tech data made available from America's space agency, Battelle will help utility companies better predict when energy supplies will be needed.

Battelle recently won a three-year, \$640,000 contract from NASA that focuses on applying high-resolution, weather-related Earth science data to key systems used by energy utilities for short-term load forecasting. Load forecasting is required by energy utilities to balance supply and load on the electric grid or to dispatch natural gas.

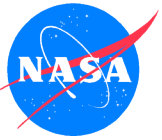
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# Conclusions

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- *Energy Management Program has and continues to yield significant results for nation and international programs through Science => Applications transfer*
- *Successes involve supporting renewable energy and energy efficient technology optimization; thus are relevant to identified priorities in climate change mitigation and adaptation.*
- *The model of success in this field has been long-term partnerships featuring the development and dissemination of specifically tailored data sets.*
- *Data sets made available through web based interfaces provide opportunities for new projects and new partnerships*